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The diode laser business is poised at a crossroads in its development. Already two clear paths have emerged. In the past half-decade the small signal processing market has been joined by products which exploit the technology's potential as a compact energy source. However, the prospective business upturn is showing all the signs of continuing to favour the former rather than the latter.

Diode laser market pauses to regroup

Everyone in the business is looking forward to a return to the better times of the late 1990s. Memories of the downturn are fresher and these will continue to colour any judgements for quite some time to come. Hopefully, the causes of the downturn will not be forgotten because the industry owes itself to avoid a repetition of the worst time in its history. Sadly it has parallels with the cyclic behaviour of the silicon IC industry. That sector follows boom-boost cycles driven by logic devices such as microprocessors. It is hoped the diode laser market will not be the arbiter of similar cycles in optoelectronics.

Companies are reconsidering their place in the scheme of manufacturing diode lasers and related products such as modules built therefrom. The current trend is for damage limitation exercises so as to limit exposure to the possibility of history repeating itself. Market leader Nortel said it is going to chop another 3,500 jobs in its optical long-haul business after Q2 2002 figures showed revenues were going to be 'flat to down 5%' compared to Q1 estimates. As a result, it may sell its optical components business in an attempt to return to profit. Like others it is refocusing - in this case on optical switching, next-generation photonic transport capabilities and end-to-end network management and intelligence. Nortel does not expect recovery in the long-haul market before late 2003 or early 2004.

Any market forecast for diode lasers will show that telecoms dominate the sector in terms of value. It is less clear whether this or optical data storage devices lead in terms of numbers shipped. Certainly, for the next five years these two areas will be the best prospects for mass producers of diode lasers.

However, any market valuation has had to take into account serious shortfalls in expectations. Such has been the drop in orders and lack of adequate response to them that the major players are in serious trouble. The seismic waves are still being felt up and down the supply chain - from devices through epiwafers to substrates. According to the Elsevier report Diode Laser Materials & Devices, the total market for diode lasers materials and devices was worth a healthy US$6.1 million in 2000. Sadly, falling demand and oversupply saw this fall to US$5.3 million in 2001. 2003 should see better results all round with a total value of US$7.0 billion, the diode laser device market progress is shown in Figure 1.

Any resumption of growth approaching that of the 1990s heydays will mean that by 2006 the total market should have broken through the US$10 billion barrier. By then the landscape will have changed considerably. Many start-ups will be memories. The late 1990s was witness to an unusual number of start-ups - probably too many to fit in the marketplace. There will be the inevitable sorting out of their numbers. This will be harsher than historical trends have seen. Today's marketplace is not conducive to survival and even the most experienced in the business are having to take drastic action. Unless you have a very strong product and have cornered the market then dissolution beckons.

The next five years is going to see the adoption of new materials, wafers and process equipment as suppliers strive to meet the need for improved economics while adding performance. This might well be accomplished via a transition from the industry standard for over a decade, the 2-in wafer to 3-in or 4-in diameter wafers. The

pressure to lower costs is going to be stronger than ever and manufacturing will have to find a way of making more from less raw materials.

The highest value tier, devices, is followed by epiwafers and finally substrates. It is the business of participating companies to add value at each stage as material is processed through to packaging and installation in the final product.

At the lowest tier is the source materials sector, i.e. the gallium and arsenic (not covered here). In this report some attention is also given to the device processing equipment sector that was worth around US$800 million in 2000 for all III-V applications, i.e. opto- and micro-electronic devices. The main emphasis is on wafers and devices and the companies which make them.

In 2000, the world market for substrates for diode lasers was approaching US$120 million. However, in the period 2000-01 the optoelectronics industry downturn produced many cancellations of orders for substrates and related materials. As a result, the market fell to well under the US$100 million market in 2001.

In the period 2000-01 the opto market downturn saw dozens of companies cancelling orders for materials for diode lasers such as epiwafers, substrates and source materials. Inventories were over-inflated and it has taken well over a year to work through the stock they had to accept.

Inevitably, a similar trend has befallen the worldwide merchant market for diode laser epiwafers. This was worth over US$250 million in 2000. Once it has moved through the downturn it should push past US$525 million by 2005.

This market downturn will now not likely be resurrected until early 2003. Only then can we expect positive growth in double figures. Return to growth will bring with it harder unit prices as demand cannot be met by suppliers. It cannot be ruled out that feast will be followed by famine. There is the possibility that thanks to the cutbacks in the manufacturing sector gearing up to meet demand will take some while to accomplish.

For the foreseeable future, the majority of diode laser manufacturers will still make do with smaller diameter (2-in) wafers until the volume their business handles mandates re-equipment and scaling up. By mid-decade the larger wafers, mainly 3-inch, will have begun to dominate. Markets will force such measures as systems companies insist that costs are as low as possible. It presents a pretty dismal future for cash-strapped players so it is not surprising that there will be more looking to outsource and let someone else find the money and the means to make the actual devices.

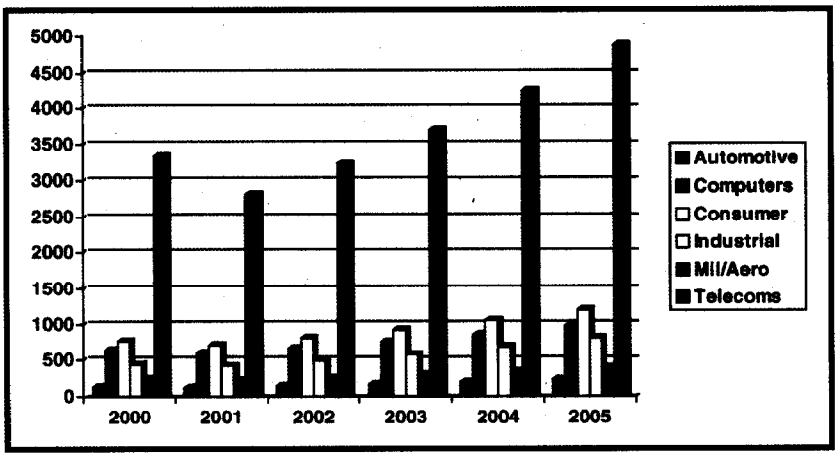
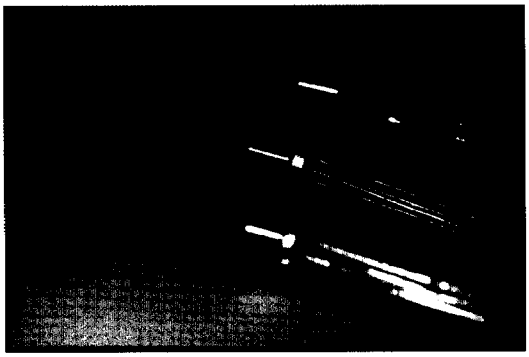


Figure 1 Worldwide Diode Laser Market by Application 2000-2005 (US$ million).

In epitaxial growth technology MOVPE is going to hold sway as it extends its gradual dominance of the diode laser business. This has been the result of its facility with the all important phosphorus compounds. The latter have made possible visible emitters which thanks to excellent sales worldwide of DVD players have helped certain parts of the industry to ameliorate their exposure in the downturn. Further good sales in this area are expected for DVD-based games consoles such as the Sony PS2 and Nintendo Gamecube. The commercial debut of recordable DVD systems is underway and these will be even more dependent on the efficient growth of higher power diode lasers.

In 2000 the world market for diode laser device was closing on the US$6 billion level, see Figure 2. Within a year it saw over a half a billion dollars worth of business shaved off that figure. This year should see that loss put back but that equates to a poor growth for two years.

However, taking the longer term view, this market will be approaching US$9 billion by 2005. It is expected to be sustained in value of sales but



AOI's new analogue 1310-nm lasers are available in industry standard coaxial packages.

Table 1 Worldwide Diode Laser Market by Device Type 2000-2005 (US$ million).

	2000	2001	2002	2003	2004	2005
FOL	3588	3025	3470	3983	4571	5247
CD	689	620	671	726	785	850
VCSEL	342	308	378	465	572	704
HPDL	285	271	335	416	516	640
Red	621	590	644	703	768	838
Violet	171	193	237	290	356	436
Total	**5696**	**5006**	**5736**	**6583**	**7568**	**8715**

FOL - fibre optic laser

there will likely be significant shifts in production emphasis by product type.

In fibre datacoms the allure of the 40 Gbit/s era is irresistible but by no means are any of the industry pundits sure of the timing of what will be another bonanza for diode lasers. Tunable laser products are preoccupying many of the main players but it is almost certain that after a period of sorting out, the systems company leaders like Cisco will have made up their mind and one or maybe two options will be taken up, the rest will be history.

At present demand for tunable sources is not building as many had hoped. This summer brought news that US company ADC closed its tunable laser facility in Jarfalla, Sweden. The Jarfalla facility was state-of-the-art with everything from InGaAsP/InP epitaxy through to packaging and testing. Such drastic measures serve as an indicator of how bad it is in the trenches.

VCSELs are another of the most promising new type of diode laser. However, they have yet to prove their obvious advantages on the grounds of reliability and so on. This is I suspect just a matter of time. Recently, market observers have suggested that 1310 nm VCSELs will become more widely used in single-mode transceivers for Gigabit Ethernet and Fiber Channel applications, for example. Electronicast says that VCSEL-based transceivers were worth $388 million in 2000 but then the market fell to $290 million in 2001. But VCSELs have so much more to offer than that so you can count on them being a major force in due course.

One bright prospect is to be found in the visible emitter arena. There will be a resurgence of visible lasers for the pointer market. This surged to record levels a few years ago then almost as quickly receded. Manufacturers fell foul of price-cutting and the banning of unsafe products. However, new legislation which allows the use of 'eye-safe' (1.5-3 μm) laser pointers should mean the return of this business not only for novelties but also more serious uses such as rangefinders, levellers and barcode readers.

Telecom lasers will resume good growth even though pricing maybe harsher than in the past. This and other sectors such as HPDLs and VCSELs will expand at the cost of optical data storage such as CD and DVD. These markets will see continued growth but pricing will be under severe pressure forcing down the overall market value and hence the contribution to the total market. Other interesting areas for growth include violet diode lasers which will break out from the high value, lower volume instrumentation market and into printing and eventually consumer and data mass storage market for the all-solid-state digital videocassette recorder. The progress of the diode laser device market by device types is shown in Table 1.

While there will continue to be good growth for all types of diode laser over the longer term, some types will perform substantially better than others. This is partly due to their position in the product lifecycle, e.g. the CD diode laser family is mature and unit prices are now very low. By contrast the violet diode laser has yet to approach the mid-part of its product cycle and so growth rates are more robust.

The diode laser market certainly has the potential to double its value within five years. Companies continue to innovate new components and thereby create new markets for new systems. Whatever happens in the next year the demand for more performance is unremitting. Behind any boom-bust cycle the fundamental trend is for stronger demand for faster and higher-volume data transfer whether it be fibre optic datacoms or optical data storage. There is thus a fortune to be made by those who can not only survive but also build market share.

Before the era of the ten billion dollar market dawns, however, the industry must get its act together. There will be more blood-letting to come but rehiring should have got back in gear again by this time next year. Players will have to be strong enough to not get carried away by panic over-ordering and inflate those inventories. These were the underlying causes of the previous catastrophe. Hopefully there will be none of the nonsense about the 'dot.coms' to contend with so there will be no excuse next time.